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Constraining the Gauged $U(1)_{L_\mu - L_\tau}$ Model by Supernova Neutrino Observation

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The $U(1)_{L_\mu - L_\tau}$ model is one of the simplest anomaly free models to feature a new gauge boson Z' by extending the Minimal Standard Model (MSM) group $G_{\text{MSM}} \equiv SU(3)_{\text{QCD}} \otimes SU(2)_{\text{Weak}} \otimes U(1)_Y \rightarrow G_{\text{MSM}} \otimes U(1)_{L_\mu - L_\tau}$. This hypothetical new gauge boson Z' could affect the cooling mechanism of a core-collapse supernova. The production of Z' in a supernova might over contribute to the energy loss depending on the magnitude of the coupling between the new gauge boson Z' and μ, τ leptons. Consequently, the SN neutrino production might be affected and contradict the recent core-collapse supernova neutrino observation, SN 1987A. We calculate the Z' production and absorption/decay rates through pair-coalescence, semi-Compton, loop-Bremsstrahlung from proton-neutron scattering, and their inverse processes in a benchmark SN simulation SFHo18.8 (Thomas Janka {\it et al.}, Phys. Rev. Lett. 125, 051104 (2020)) and put constraints on the coupling constant in this new gauged $U(1)_{L_\mu - L_\tau}$ model. Although such constraints were studied in previous literature, our study gives more stringent constraints on the model by carefully considering the competition between Z' production and absorption/decay effects to Z' luminosity at the very outermost shell of the neutrino sphere. We point out that Z' luminosity will tend to a constant plateau value depending on $m_{Z'}$ instead of monotonically decreasing down to zero as the coupling constant increases. This plateau phenomenon can be understood by physical arguments and justified by numerical calculations. We found that the plateau value of Z' luminosity will become greater than Raffelt's criterion when $m_{Z'}$ is lower than a specific value ~ 2 eV. For $m_{Z'} < 2$ eV, the so-called trapping limit shall disappear completely. We stress that the plateau behavior of Z' luminosity in the large coupling limit should also occur for other BSM models that introduce new light bosons. Hence our work has extended applications.

In-person participation

Yes

Primary authors: Mr LEUNG, Chun Sing Jason (Institute of Physics, National Yang Ming Chiao Tung University, Taiwan); Prof. LIN, Guey-Lin (Institute of Physics, National Yang Ming Chiao Tung University, Taiwan); Prof. LAI, Kwang-Chang (Chang Gung University, Taiwan)

Presenter: Mr LEUNG, Chun Sing Jason (Institute of Physics, National Yang Ming Chiao Tung University, Taiwan)

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